



Saudi Arabia - production forecasts and reserves estimates

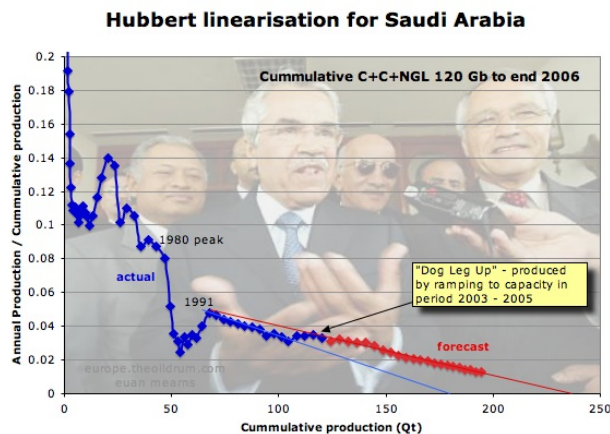
Posted by [Euan Mearns](#) on August 30, 2007 - 10:27am in [The Oil Drum: Europe](#)

Topic: [Supply/Production](#)

Tags: [aspo](#), [colin campbell](#), [original](#), [production forecast](#), [reserves](#), [saudi arabia](#)

[\[list all tags\]](#)

In his recent post, Ace assumes ultimate recoverable reserves (URR) in Saudi Arabia to be 175 Gb (billion barrels). With 112 Gb already produced, that leaves only 63 Gb remaining. **Colin Campbell (the founder of ASPO)** has estimated total reserves for Saudi Arabia of 275 Gb (news letter 66), believed to be C+C+NGL (crude oil + condensate + natural gas liquids). There is an enormous discrepancy between this and Ace's analysis that ought to be explained.



This post is a brief summary of my views on Saudi reserves and production. My conclusion is that Saudi Arabia likely has at least 120 Gbs of remaining reserves (C+C+NGL) for a URR in excess of 240 Gbs (C+C+NGL). The remaining reserves according to this analysis are almost double those reported by Ace.

The importance of reserves and production forecasting

The point I have reached in my analysis of peak oil and energy decline is that reserves and production forecasting are of paramount importance. It seems increasingly likely to me that Planet Earth has ample supplies of alternative energy that may be gathered (nuclear and **renewable solar sources**) and which may replace declining fossil solar fuels when that happens. The major challenge that confronts us is not a lack of energy or engineering solutions but one of political, institutional, corporate and personal behaviour. The human race seems intent upon running for the edge of an energy cliff. Persuading politicians and OECD institutions now that energy decline is a very serious threat to the future of industrial civilisation is the single most important task that confronts us. Reliable and credible energy forecasts lie at the heart of that task.

Forecasting oil, gas, coal, uranium reserves and production is a highly complex process, not to be taken lightly. It is therefore with some reservations that I present this view on Saudi Arabian

The Oil Drum: Europe | Saudi Arabia - production forecasts and reserves estimates <https://europe.theoil Drum.com/node/2910>
reserves and production as I simply do not have all the information required to do this job reliably. This seems an appropriate time to quote Colin Campbell's 10th commandment:

ALL NUMBERS ARE WRONG – THE QUESTION IS : BY HOW MUCH ?

I will follow a combined bottom up and top down approach, drawing on the work [Stuart Staniford](#) and [I](#) have done on Ghawar, [Aramco reserves estimates](#) (pre-nationalisation based on BP data), [Aramco forecasts for new projects \(pdf\)](#) and [Hubbert linearisation](#).

Why C+C+NGL

All the figures presented here are for C+C+NGL making direct comparison with Ace who has used C+C only, problematic. My apologies for that, but I have good reasons for doing so.

The first is laziness. I find the [BP statistical review of world energy](#) to be a very readily accessible source of data which I use all the time - and BP quote C+C+NGL.

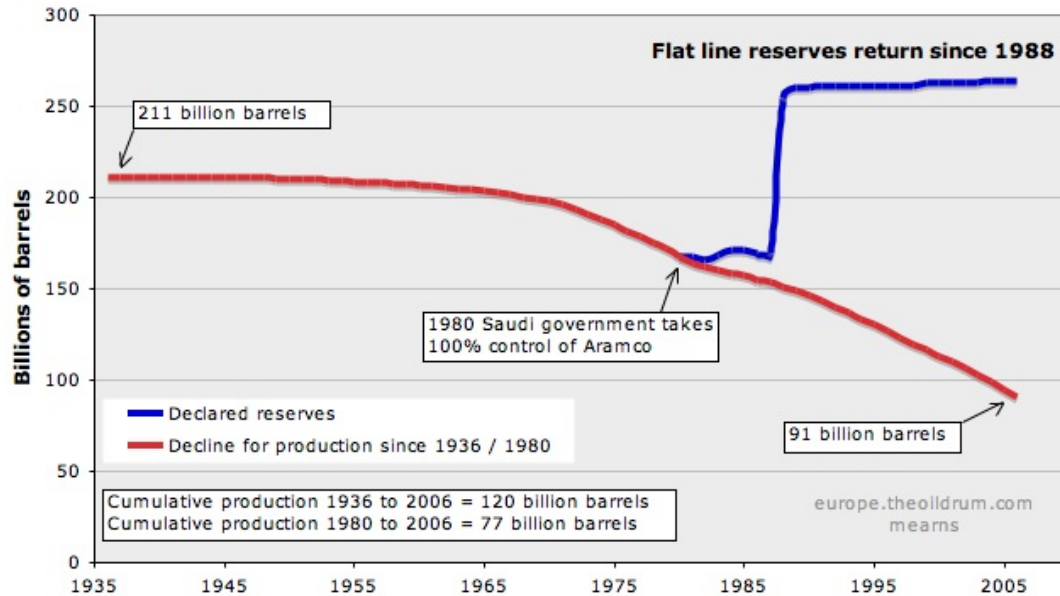
The second is the fact that NGL is a vital constituent of any petroleum system. In simple terms, the kerogen rich petroleum source rocks produce progressively lighter hydrocarbons with increasing pressure and temperature during burial. Starting with crude oil, the kerogen will then produce light oil, condensate, wet gas and once it is near completely cooked it will produce dry methane. So NGL, which condenses out of wet gas is a vital constituent of any petroleum system and should not be ignored in my opinion.

And third, gas production in the Middle East has been relatively low to date owing to remoteness from European and North American markets that historically have been served by local sources of gas. With increasing amounts of liquefied natural gas (LNG - not to be confused with NGL) now being produced, NGLs are tending to make up a significant amount of new production that is coming on stream. Ignoring NGLs at this stage, therefore, may present an unduly pessimistic picture.

However, it must also be pointed out that the energy content of Saudi NGL is about 70% of Saudi crude oil. So 1 barrel of NGL is not equivalent to 1 barrel of crude oil in energy terms. No adjustment has been made for the differing energy contents.

Saudi official reserves and their decline

Saudi Arabia Oil Reserves

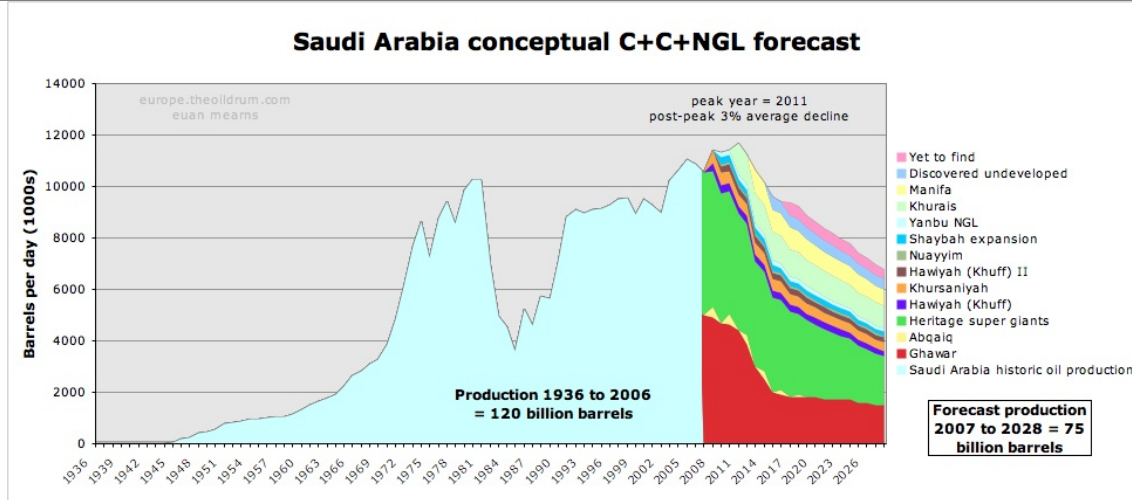


The starting point for this analysis is to look at the official Saudi reserves estimates for 1980 as stated in the BP Statistical Review. A figure of 168 Gbs is quoted. This is the figure carried by Aramco when it was run by American companies, pre-nationalisation. As far as we know, this was an objective assessment of recoverable reserves at that time. Since 1980, Saudi Arabia has produced 77 billion barrels and declining the 168 figure for this production leaves 91 billion still to be produced, an observation made by Robert Rapier in [an earlier post](#).

However, since 1980 there have been significant improvements in production technology, in particular the advent and widespread use of horizontal wells and 3D and 4D seismic that enable more accurate targeting of by-passed oil. This has led to an improvement in recovery factors since 1980, and the figure of 91 Gbs remaining may justifiably be adjusted upwards to account for this.

Using the API Facts and Figures Centennial edition (1959) production data from 1936 to 1966 and BP production data from 1966 to 2006 shows that Saudi Arabia has produced 120 Gbs to date. Anchoring the production decline profile (the red line) on 1980 points to initial recoverable reserves of 211 Gbs with 91 Gbs remaining. But as already stated, these numbers should perhaps be adjusted upwards to account for improved recovery factors.

Conceptual production forecast



Forecast numbers are production capacity. Actual production may be lower depending upon demand. Click all charts to enlarge

The conceptual production forecast for Saudi Arabia has the following assumptions:

Ghawar

The Ghawar forecast is based on the base case revision 1 model I presented [here](#). This is truly a bottom up analysis based on combining the reservoir volume determined from published maps and reservoir data combined with estimates made of the depletion state of the field estimated from published 3D models. The step down in production in the interval between now and 2017 represents the gradual death of northern Ghawar and transferral of production to the south which is much less depleted and may sustain a reduced plateau for many years.

Between now and 2028, 21 Gb of production is shown of an estimated 40 Gb remaining reserves. Some time beyond 2028, Ghawar production will go into rapid decline as the south end of the field becomes exhausted.

Abqaiq

Abqaiq is the most mature of the Saudi supergiants. The status of Abqaiq is rather obscure. The Linux map discussed [here](#) and subsequent posts shows oil remaining only in the crest and ridges of the structure. [Jaffe and Elass](#) (pdf) show zero production for 2004, although this may be clouded by periodic inclusion of Abqaiq production together with Ghawar. [Multi-phase pumps](#) (pdf) have been deployed to help produce the remaining oil.

Abqaiq is an ageing queen that no doubt would benefit from periodic rest and I have therefore conceptually shown sporadic annual production of up to 400,000 bpd that is turned on when needs require. A total of 657 million barrels of Abqaiq production is in the model.

Heritage super-giants

The heritage supergiants are those mature fields that together with Ghawar and Abqaiq have made up Saudi production for the last 50 years. These include Safaniyah, Berri, Shaybah, Qatif, Marjan, Zuluf, Abu Safah and the Hawtah trend fields. These fields are much less mature than Ghawar and it is difficult to estimate their future performance. The oil in Safaniyah, Zuluf and Marjan is very sour (contains high sulphur content) which creates refining and hence marketability problems. I consider it likely that these fields are not producing flat out but are production constrained owing to poor marketability of their oil. The Saudis are taking steps to increase their own refining capacity to deal with this problem.

It is difficult to know what decline rate to apply to this group of fields. Some, like Safaniyah and Shaybah may not decline at all in the foreseeable future. Whilst others like Berri and the smaller Hawtah trend fields may experience more rapid decline in the years ahead. [Jaffe and Ellass](#) report natural decline rates of 7 to 8% that is stemmed to 2% by intervention. In the interest of being conservative, I have declined the heritage assets at a rate of 5% per annum. This may prove to be too high. They contribute 27.5 Gbs to 2028.

New Fields

New Fields are based on the [Saudi Aramco projects time line](#), posted by Ace. Project delays have been a common feature of the recent commodities bull run and delays have therefore been built into the model.

Hawiyah (Khuff), Khursaniyah, Hawiyah (Khuff) II, Nuayyim, Shaybah expansion and Yanbu NGL have all been delayed by one year. Khurais and Manifa have been delayed by 2 years.

Two projects - 2007, Khursaniyah ethane+NGL, 290,000 bpd and 2008 Yanbu ethane + NGL, 195,000 bpd - are not included because it is not clear that these are genuine liquids projects. Ethane is a gas.

The new projects are all included at their nameplate capacity but are declined at a rate of 2% per annum thereafter.

Discovered undeveloped

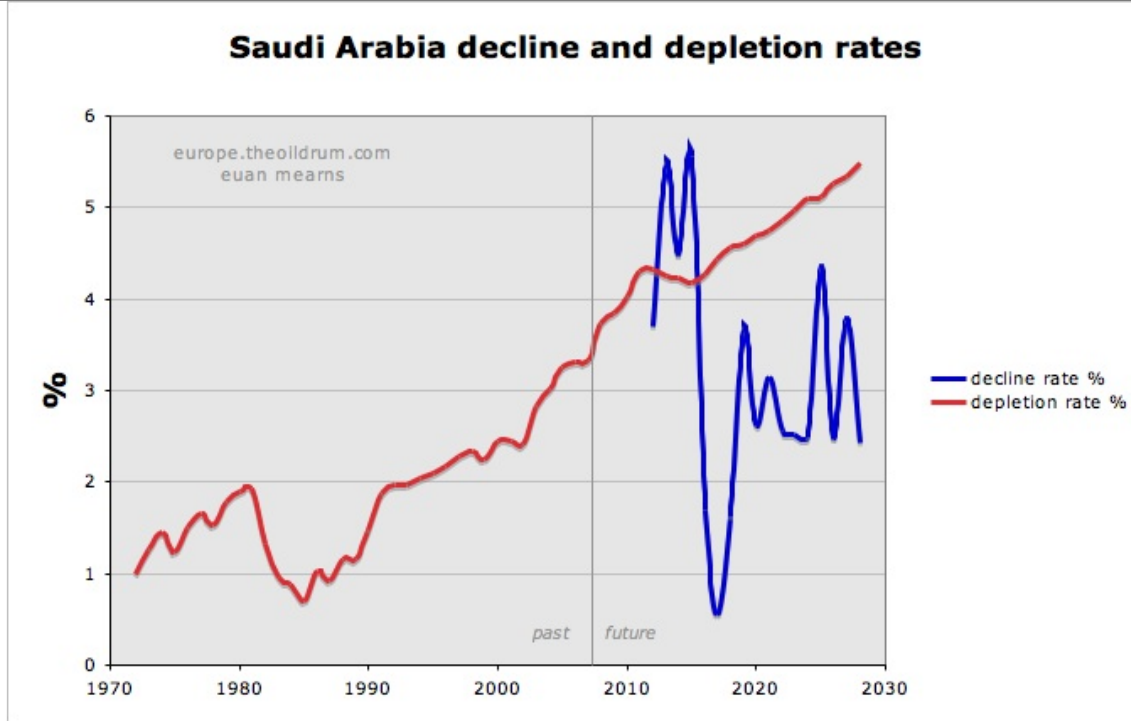
A 500,000 bpd allowance is made for discovered undeveloped fields from 2015 that are declined at 2% per annum thereafter.

Yet to find

A further 500,000 bpd allowance is made for fields as yet undiscovered from 2017 (10 years from now) that too are declined at 2% per annum.

All this is speculative and conceptual. It seems unlikely in an oil rich country like Saudi Arabia that oil developments will grind to a halt after Manifa - thus it seems prudent to include some allowance for these future but as yet undetermined projects.

Putting all this together provides the conceptual production forecast model shown above. The peak in liquids production is 2011 and the average post-peak decline is 3%. The modelled decline and depletion rates are shown below. Depletion is based on a URR of 240 Gbs (see the following section). The reserves depletion rate cannot go on rising forever, and at some point in the future, the death of S Ghawar (and other supergiants) will lead to periods of accelerated decline that will lower the reserve depletion rate.



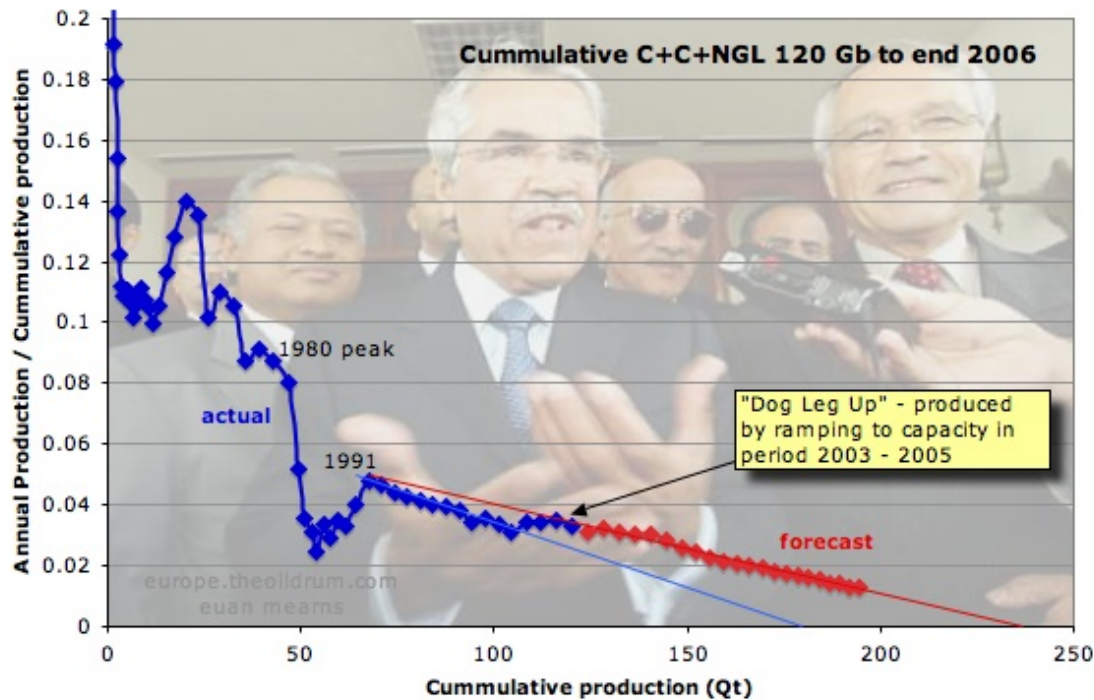
*Decline rate = year on year change as % of production that year.
 Depletion rate = annual production as % of remaining reserves based on an assumption of 240 Gbs URR (see following section)*

Asset	Production allocation 2007-2028 Gbs	Hydrocarbon
Ghawar	20.9	Arab light
Abqaiq	0.66	Arab light
Heritage assets	27.5	mixed, biased sour
Hawiyah (Khuff)	2	NGL
Khursaniyah	3.2	Arab light
Hawiyah (Khuff) II	1.6	NGL
Nuayyim	0.61	Super light
Shaybah expansion	1.5	Extra light
Yanbu NGL	1.2	NGL
Khurais	6.7	Arab light
Manifa	4.5	Arabian heavy
Discovered undeveloped	2.2	
Yet to find	2.0	
Total 2007 to 2028	75	

Hubbert Linearisation

Regular readers of The Oil Drum will recognise this Hubbert Linearisation (HL) chart that I have posted many times on various threads. When it was first posted it received cries of derision from certain posters because my favoured trend is the "stretch HL" drawn between 1991 and 2005 (the red line). How could anyone have the audacity to draw a trend between two points pointing

Hubbert linearisation for Saudi Arabia



Saudi oil minister Ali I. Al-Naimi holds Saudi Oil production and the future of industrial civilisation in his hands

The logic is this:

We know for sure that in the period 1991 to 2002, Saudi Arabia was not pumping at capacity. The southern third of Ghawar (Haradh) wasn't even developed and numerous discoveries were standing idle, we saw \$10 oil in 1998 and Saudi Arabia probably had over 2 million bpd spare capacity. The linear trend from 1991 to 2002 therefore does not see all the reserves and it seems highly likely that this will underestimate the Saudi resource.

1991 (GW I) and 2005 were two years that Saudi Arabia was likely pumping at or near capacity. It is hypothesised that had they pumped at capacity for the interim period then the HL would have declined along the red line and would be pointing towards 240 Gbs.

The red symbols represent the production forecast detailed above and needless to say I was fairly satisfied to see these lining up along my stretch HL trend. This doesn't make it right, but it certainly adds a degree of internal consistency. 2006 production is the last blue symbol.

There has been much debate about HL on TOD over the past year ranging from those such as [Westexas](#) who have blind faith in the method to [Robert Rapier](#) who has expressed doubts that HL has predictive qualities. I have always adopted a moderate view acknowledging usefulness so long as the limitations are recognised and understood. On this basis for the time being my view on Saudi reserves of C+C+NGL is that these will be at least 240 Gbs.

Downside risk

Stuart has recently circulated an internet chart of Ghawar production that shows 4 million barrels per day (mmbpd) for 2007. This is about 1 mmbpd lower than shown in my production model. The provenance of this data is unknown, as is its reliability. 4 mmbpd, however, matches anecdotal evidence from other sources considered to be reliable.

The reduction in Ghawar of 1 mmbpd over 2 years as indicated on this chart matches the decline in Saudi production over the same period. This brings us back to the question of why Ghawar production may have fallen at a rate of 10% per annum for two years?

One possibility is that the depletion state of Ghawar is more advanced than was concluded in [my analysis](#) and that Ghawar is now on the slide indicated in my forecast to begin in 2011. It is therefore within the realms of possibility that the Saudis have been caught unprepared for a collapse in N Ghawar production, and the [scramble for rigs and new projects](#) that is now underway has come too late to forestall a drop in their productive capacity. The alternative explanation is that mature [parts of N Ghawar are being rested](#) to allow new wells to be drilled and reservoir pressure to rise etc.

Bringing N Ghawar decline forward by 4 years produces a modified forecast in the near term. Saudi watchers will note that 2005 becomes the peak year in a 30 year undulating plateau spanning 1990 to 2020. 5 billion barrels production are lost in the period to 2028 relative to the base case forecast presented above.

Summary

	URR Gb	Remaining Gb	Recovery %	Notes
Ace	175	63	25	C+C only
Pre-nationalisation	211	91	30	minimum
Mearns	240	120	34	minimum
Campbell	275	155	39	
Saudi official	384	264	55	BP+produced

The recovery factors are based on an assumed 700 Gbs of original oil in place. This is the figure reported by [Baqi and Saleri](#) and by Colin Campbell.

The projected recovery factor for the official Saudi reserves is unrealistically high for the whole country. 55% may be achieved in the N Ghawar production sweet spots but most certainly not in poorer quality reservoirs that make up much of the countries resource base.

In his analysis, Ace concluded:

it is now almost a certainty that Saudi Arabia passed peak C&C production of 9.6 mmbd in 2005

In reaching this conclusion, Ace assumed that Saudi Arabia had no market for most of its sour crude oil and allocated only 20 billion barrels to sour crude reserves whilst acknowledging that the actual figure may be much higher. 85 Gbs recoverable reserves were booked for Ghawar, whilst [Stuart's analysis](#) suggested 96 Gbs and [my base case analysis](#) suggested 97 Gbs. Not all new projects were included at nameplate capacity and NGL is not included in this analysis of C+C only. It seems that worst possible case assumptions have been made at each stage which not

The Oil Drum: Europe | Saudi Arabia - production forecasts and reserves estimates <https://europe.theoil Drum.com/node/2910>
surprisingly then leads to a low estimate of reserves and a picture of imminent production collapse. The indicated country-wide recovery factor of 25% is very low.

Campbell's analysis of Saudi reserves is rather superficial. He recognises official Saudi estimates of original oil in place to be 716 Gb but prefers a figure of 600 Gb based on anecdotal evidence from reliable sources. A generous 45% recovery factor is applied to the 600 Gbs to get a figure of around 270 Gbs. This figure matches Saudi official reserves estimates and it is suggested that the Saudis report URR and not remaining reserves. This certainly fits the practice of showing no decline in the annual reserves return.

Time to recall Colin Campbell's 10th commandment:

ALL NUMBERS ARE WRONG – THE QUESTION IS : BY HOW MUCH ?

It is up to individual readers to decide where the truth lies.

Acknowledgement

Professor Goose, Stuart Staniford, Khebab, Luis de Sousa and Ace reviewed the text and provided helpful comments. This does not mean they necessarily agree with the content.

Further articles on The Oil Drum about Saudi Arabia:

by Stuart Staniford

- [Saudi Arabia and Gas Prices](#)
- [Depletion Levels in Ghawar](#)
- [The Status of North Ghawar](#)
- [Further Saudi Arabia Discussions](#)
- [Water in the Gas Tank](#)
- [A Nosedive Toward the Desert](#)
- [Saudi Arabian oil declines 8% in 2006](#)

by Euan Mearns

- [Ghawar reserves update and revisions \(1\)](#)
- [GHAWAR: an estimate of remaining oil reserves and production decline \(Part 2 - results\)](#)
- [GHAWAR: an estimate of remaining oil reserves and production decline \(Part 1 - background and methodology\)](#)
- [Saudi production laid bare](#)
- [Saudi Arabia and that \\$1000 bet](#)

by Heading Out

- [Simple mathematics - The Saudi reserves, GOSPs and water injection](#)
- [Of Oil Supply trains and a thought on Ain Dar](#)

by Ace

- [Updated World Oil Forecasts, including Saudi Arabia](#)
- [Saudi Arabia's Reserve "Depletion Rates" provide Strong Evidence to Support Total Reserves of 175 Gb with only 65 Gb Remaining](#)
- [Further Evidence of Saudi Arabia's Oil Production Decline](#)



This work is licensed under a [Creative Commons Attribution-Share Alike 3.0 United States License](https://creativecommons.org/licenses/by-sa/3.0/).